Climate change impacts on severe thunderstorms in Finland

Andrea Vajda and Jenni Rauhala
Finnish Meteorological Institute, P.O.Box 503, FIN- 00101 Helsinki

MOTIVATION

Connections between climate change and changes in the frequency and intensity of severe thunderstorms are still mainly unexplored due to the limitations given by the resolutions of the climate models.

The objective of this study is to estimate the possible changes in frequency of severe thunderstorms in Finland under one of the projected future climate scenarios. Ingredients based approach is used for finding out the environmental conditions favorable for severe thunderstorms in Finland.

The results highlight the challenges in the study of climate change impacts on severe storms: apparent variability of favorable environments and difficulties of the climate models to reproduce meso and synoptic scale processes.

DATA

- High-resolution (25 km) regional climate model: SMHI-RCA-BCM from ENSEMBLE project driven by SRES A1B emission scenario
- Integration over two periods:
  - control run describing the present climate (1971–2000)
  - scenario run corresponding to future climate (2071–2100)
- Data for surface and seven vertical levels: 1000, 925, 850, 700, 500, 300 and 100 hPa
- Daily mean air temperature, dew point temperature and wind data
- Tornado and large hail observations for Finland during 1971–2000

IDENTIFYING THRESHOLDS FOR SEVERE STORM ENVIRONMENTS

Height of LCL - Lapse rate 850-500 hPa - Surface-6 km wind shear

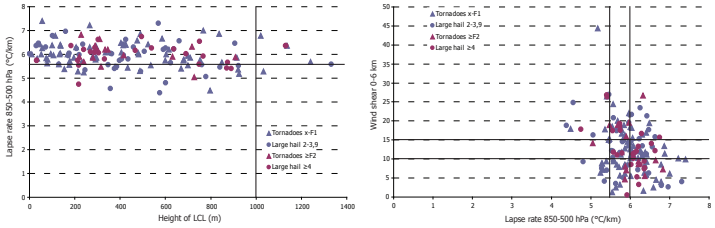

Figure 1. Distribution of severe storm environments for observed hail and tornado cases (1971-2000).

- Based on the current climate simulation, most of the tornado and large hail environments in Finland (1971–2000) have 850–500 hPa lapse rate between 5 and 7 °C/km.
- Except for couple of cases, all had LCL values below 1000 meters (Fig.1 left).
- The 0–6 km wind shear (vector difference between surface and 500 hPa winds, Fig.1 right) values have vast range, with a large portion of environments with values bellow 10 m/s, which are not generally considered favorable for severe storms.
- With significant events one would expect higher lapse rate and higher 0–6 km shear values, but there are no major differences between the significant and weak events in the dataset.
- The 925–700 hPa lapse rate and 0–1 km vertical wind shear was also studied for all tornado and large hail environments but those did not seem to describe the environment properly.

Probability (%) of tornado and large hail events to occur in given environments (1971-2000)

LAPSE RATE (850-500 hPa)	WIND SHEAR (0-6 km)									
	Any wind		≥ 10		≥ 15		≥ 20		≥ 25	
≥ 5	0.52	0.46	0.48	0.25	0.37	0.30	0.30	0.09	0.22	0.11
	0.14	(6)	0.08	(1)	0.11	(3)	0.04	(0)	0.11	(0)
≥ 5.5	0.52	0.44	0.49	0.38	0.36	0.29	0.28	0.11	0	0.15
	0.12	(22)	0.06	(5)	0.10	(6)	0.06	(1)	0.15	(0)
≥ 6	0.52	0.27	0.36	0.23	0.26	0.11	0.26	0.09	0	0.26
	0.09	(14)	0.02	(7)	0.04	(2)	0.09	(0)	0.26	(1)
≥ 6.5	0.19	0.13	0.16	0.04	0.07	0	0	0	0	0
	0.05	(5)	0	(1)	0	(0)	0	(0)	0	(0)

- Probability of hail events (blue), tornadoes ≥F1 (red) and tornadoes ≥F2 (green) were computed using the frequency of different storm environments in the control run. The number of tornadoes (≥F1) for each category are shown in black.
- The best criteria for storm environment (STE) was chosen based on the number of observed events for each threshold interval and the probability.

STE 1	STE 2	STE 3
LCL ≤ 1000 m	LCL ≤ 1000 m	LCL ≤ 1000 m
LR ≥ 5.5 °C/km	LR ≥ 5.5 °C/km	LR ≥ 6 °C/km
W0-6km ≥ 10 m/s	W0-6km ≥ 15 m/s	W0-6km ≥ 10 m/s

Are these storm environments applicable for Finland?

SPATIAL DISTRIBUTION OF SEVERE STORM ENVIRONMENTS

- The frequency of favorable storm environments based on RCM control run significantly overestimates severe storm situations (Fig. 2).
- One reason of overestimation is probably the unusually low values obtained for the height of LCL (Fig. 3) due to the used daily mean values (the only available in RCMs)
- New adjusted thresholds based on literature were applied:

STE 4	STE 5
LCL ≤ 1000 m	LCL ≤ 1000 m
LR ≥ 6.5 °C/km	LR ≥ 6.5 °C/km
W0-6km ≥ 15 m/s	W0-6km ≥ 20 m/s

- The frequency of severe storm environment (STE 4 and STE 5) in the present-day climate (Fig. 4) is the highest in southern Finland (over 35 cases/year and 14 cases/year respectively).
- The lowest frequency occurs in Lapland: 30-15 cases/year and 12-6 cases/year; however the estimated frequency is still higher than the number of observed cases.
- RCM indicates a negative trend in the variation of severe storm environment for the future climate.
- The decrease in frequency is more significant in the southern region of Finland (15-30%), area shifted to central Finland in future with 25-35 (STE 4) and 10-14 (STE 5) cases/year.
- At high latitudes (66° N) the distribution of favorable storm environments is indicated to decrease by 5 (STE 4) and 2 (STE 5) cases/year.

DISCUSSION

- The use of the available time resolution (daily) in RCMs seems to have significant impact on surface-6 km wind shear, on LCL values and possibly also on 850-500 hPa lapse rate.
- The daily time resolution most likely reduces the vertical wind shear values. In the real atmosphere the shear values are largely influenced by synoptic and mesoscale processes.
- Daily mean temperatures are lower than daytime temperatures, when most of severe weather occurs → lower LCL values.
- The most likely area for favorable severe thunderstorm and tornado environments is in southern Finland.
- RCM projects a decrease in the probability of severe storm environments by 2099.

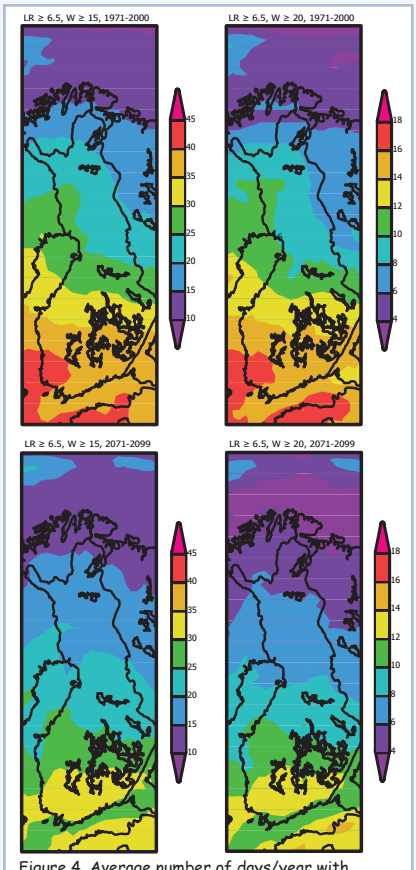

Figure 4. Average number of days/year with storm environment 4 and 5 during 1971-2000 (top) and 2071-2099 (bottom).

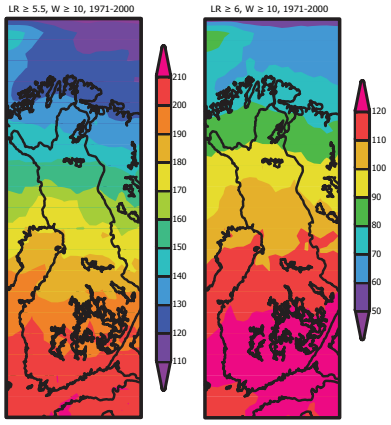

Figure 2. Average number of days/year with storm environment 1 and 3 during 1971-2000.

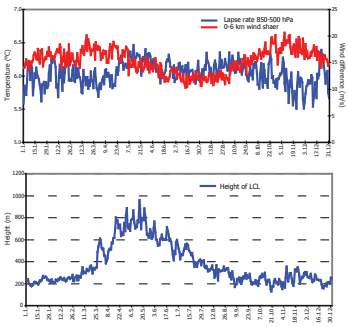

Figure 3. The multiannual variation of daily STE parameters in Jokionen, southern Finland.